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Indicator of energy efficiency applied to motorways.

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A first step: funcional unit´s lca

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The objetive of the Spanish project called Oasis is to define the main highway of the future, one that in its operation presents higher levels of safety, service and sustainability.

The subproject PT 6 is studying a methodology to develop an **indicator on energy efficiency**, to evaluate the amount of energy linked to a motorway, during its complete **life cycle**. The **methodology** will define the criteria which will unify these complexities from a general point of view. For example, this methodology will be applied to find an indicator which will measure the embodied energy throughout the life cycle of the motorway. This **indicator** is open to be extended to and joint to other indicators, to reach a whole scope of sustainability. The basis is to consider the motorway in its **whole dimension** and scope. This means that the aim is to include, in one single index, the embodied energy in the cycle of its whole useful life and in the multiple aspects in which this index, including traffic, is appropriate.

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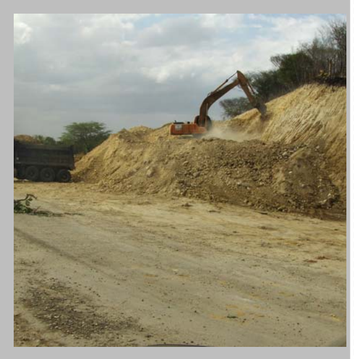
1. what is the energy footprint of a motorway?

the motorway consumes and produces energy...

The principal aim of the study consists of developing a methodology to calculate the energy associated with a motorway's complete life cycle, obtaining its energy footprint. Energy is consumed by the extraction of raw materials, production of materials, work, etc.. and especially by vehicles passing through it. But it can also produce energy from renewable resources by taking advantage of the shoulders, placing solar panels on buildings to operate the motorway, re-using waste of deconstruction, etc.

The objective is to evaluate the result of both energies (consumption and insumption) as the balance between the energy consumed through the process and the energy produced by the motorway at all stages of the life cycle (the energy footprint).



EX ENERGY + IN ENERGY = B BALANCE

design	construction	maintenance	traffic	deconstruction		
$- \Sigma[x_n UF_n(c)]$	$- \Sigma[x_n UF_n(c)]$	$- \Sigma[x_n UF_n(m)]$	$- \Sigma[x_n UF_n(t)]$	$- \Sigma[x_n UF_n(d)]$		
design	construction	maintenance	traffic	deconstruction		
$+ \Sigma[x_n UF_n(c)]$	$+ \Sigma[x_n UF_n(c)]$	$+ \Sigma[x_n UF_n(m)]$	$+ \Sigma[x_n UF_n(t)]$	$+ \Sigma[x_n UF_n(d)]$		

2. how to calculate the energy footprint?

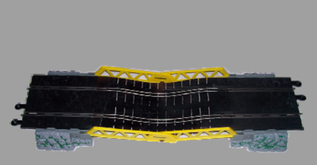
describe scenarios...

This first step is defined by all of the fixed elements that have no possible alternatives. They are a function of climatic and geographical conditions, the type of motorway, etc.. and represent the framework to compare different layout alternatives.

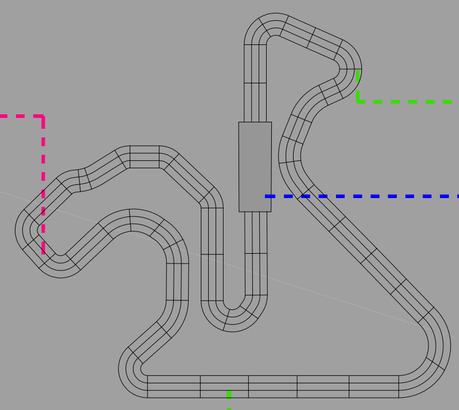
split in functional units...

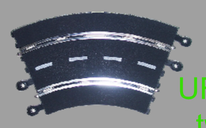
Functional units are elements within the motorway's design with optional features, and make up part of the structural repertoire of all stretches. Each functional unit is associated with an energy index. The set of functional units in the strech are susceptible to comparison with the stretches of different offering parties or of the different possible solutions.

$IUF^{(m)}_{(EX)} + IUF^{(m)}_{(IN)} = IUF^{(m)}$


UF P2 two-line bridge
Σ + Σ = B


UF C2 two lines
Σ + Σ = B

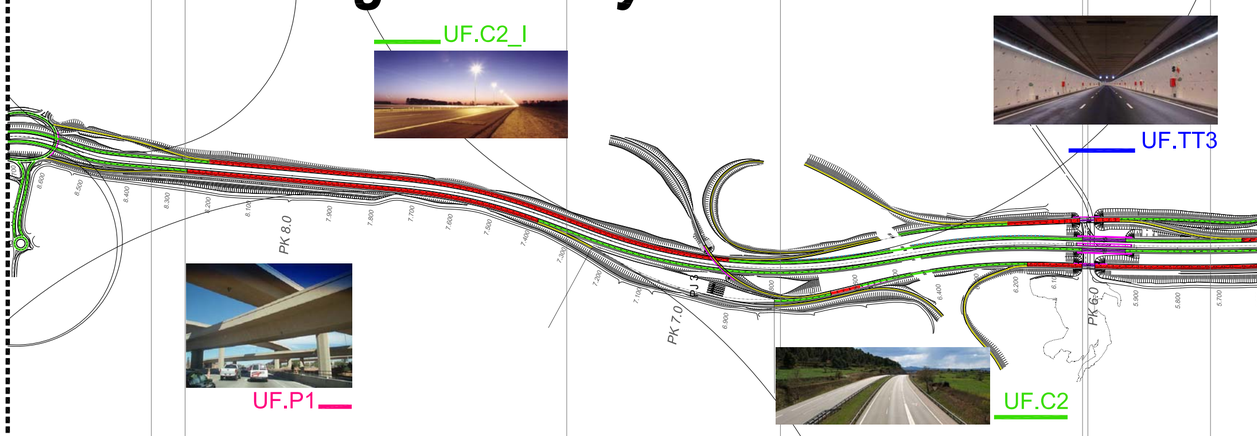



UF C2-R2 two lines radius of curvature 2
Σ + Σ = B

UF T2 tunnel
Σ + Σ = B

3. could you give an example?

in an existing motorway...

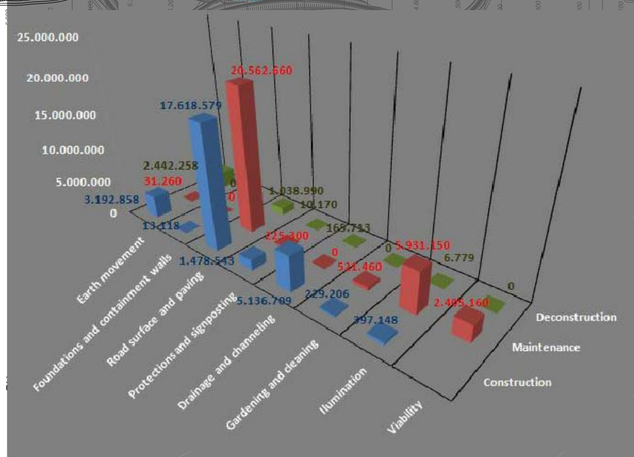


Currently the discussed methodology is being applied to evaluate a single functional unit, specifically *'1 Km stretch of the motorway, with a 30 m path, with two roads, two lanes and shoulders'*, with the aim of validating and verifying its proper performance. With this first functional unit, the tool's efficacy has been checked in a complete life cycle analysis

M-12 motorway Madrid = 40,7 km = 36 km **UF.trunk** + 0,8 km **UF.bridge** + 3,8 km **UF.tunnel**

conclusions

Taking the previous highway as an example, the procedure for a straight UF of two lanes has been verified. In this case no energy was produced, and therefore the in - energy was zero. As a conclusion, the energy balance of the total life cycle of this UF is (+1,008,810.776 MJ), considering design and construction (2,78%), operation (2,84%), traffic (93,91%) and deconstruction (0,36%).



The sum of the energetic consumption of the rest of UF's will provide the energy footprint of the highway. Knowing beforehand the average consumption of the UF's, we can assess the energetic footprint of a route in its preliminary plan phase, comparing alternatives, and promoting the use of energy from renewable resources, facilitating the decision making process in every step of the life cycle.

life cycle phases UFc2	MJ	%	%
CONSTRUCTION	28.066.161	2,78	5,72
MAINTENANCE	29.676.990	2,94	
LVT	563.724.168	55,88	93,91
HVT	383.679.547	38,03	
DECONSTRUCTION	3.663.910	0,36	0,36

3. could you give an example?

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